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Traffic and soil amendment effects on infiltration and compaction

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Traffic and Soil Amendment Effects on Infiltration and Compaction

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Abstract

Poor soil physical properties that limit water movement, root development, and soil aeration are believed by many to be a continuing barrier to increased crop yields. Soil conditioners supposedly modify the soil environment providing benefits such as improved water infiltration, decreased soil compaction, improved soil structure, and improved crop yields. This study was undertaken to determine the effects of a soil conditioner, ammonium laureth sulfate, and two levels of vehicle compaction on several of these properties.

There were no statistically significant effects of ammonium laureth sulfate on soil water infiltration, soil penetration resistance, soil bulk density, soil water content, nor crop yields. Additionally, there were no interaction effects of the soil conditioner with the level of compaction caused by vehicular traffic. However, increased trafficking did cause increased soil compaction with resultant significant effects on penetration resistance, soil bulk density, soil water content, and soil water infiltration.

For the short term, there seems to be no benefit associated with using the ammonium laureth sulfate conditioner. Studies of the longer-term effects of this conditioner on soil properties and yields for various locations and soils may be warranted. Presently, farmers are advised to concentrate on more traditional methods of maintaining a favorable soil environment for crop growth. Soil compaction can result because of vehicular traffic, and farmers should be aware of the possible detrimental effects on soil physical properties and resultant yields.

Introduction

Soil conditioners are advertised and sold as products to advantageously modify the soil environment and provide benefits for tillage and crop production. Many products supposedly result in increased yields while simultaneously providing improved conditions for water infiltration, decreased soil compaction, and other favorable properties (see Wallace and Nelson, 1986, for a brief discussion). In addition to short-term yield increases, soil conditioners may provide benefits to the soil-plant system through better trafficability, decreased erosion, and improved soil structure. Different soil conditioners are used by farmers and ranchers, and questions continue to arise from the agribusiness community about the benefits and attributes of these products. These inquiries are often directed toward research and extension personnel and include questions concerning potential benefits, the economics related to use, and appropriate rates and times of application.

Evaluations of soil conditioners, such as polyacrylamides and polysaccharides, have been ongoing for many years as evidenced by the early reports of Martin (1953), Sherwood and Engibous (1953), and Quastel (1954). A common theme is that one of the continuing barriers to moving further up the crop-yield ladder is poor physical properties of the soil with resultant limitations of water movement, root development, and soil aeration. Investigations of soil conditioner effects have continued into recent years with reports by Callebaut et al. (1979) and, more recently, the entire May 1986 issue of *Soil Science*. Soil properties that have exhibited beneficial effects from soil conditioner treatments include soil water infiltration, soil bulk density, soil penetrometer resistance, aggregate stability, surface crusting, and hydraulic conductivity. Although results are not uniform, beneficial effects of polyacrylamides are more consistent, have greater longevity, and are more pronounced than benefits from polysaccharides (Wallace, 1986; Wallace and Wallace, 1986; Mitchell, 1986).

Sherwood and Engibous (1953) found that infiltration rates were significantly improved in soils treated with polyacrylamide (PAM) conditioners. In a more recent study, Callebaut et al. (1979) also found increased hydraulic conductivities resulting from PAM treatment of soil cores. Terry and Nelson (1986) reported up to twice the infiltration rates for PAM-treated plots as contrasted to control plots. However, Mitchell (1986), conducting irrigation infiltration tests on a silty clay loam with 50% clay, found that infiltration rates and total infiltrated water were not increased by a PAM conditioner. Wallace et al. (1986) indicated that the ability of a polymer to improve water penetration varied with soil type and was not always correlated with the amount of conditioner used. Sandy soils showed less favorable results, with loam soil consistently responding favorably, and clay soil giving good but inconsistent response to conditioner treatments. Wallace (1986) indicated that a polysaccharide (guar) did not give strong water-stable aggregates and that any effects of the soil conditioner were short-lived.

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OBJECTIVES

A surfactant, ammonium laureth sulfate (ALS), is being marketed as a soil amendment that will benefit soil physical properties, increase infiltration thereby decreasing runoff, and improve crop yields. However, there is a scarcity of scientific data that supports or contradicts these claims. The data reported herein resulted from a study of the effects of ALS on selected soil properties of a Nicollet silt loam in central Iowa.

The study included an evaluation of the effectiveness of the ALS treatment on water infiltration, soil penetration resistance, soil bulk density, and soil water content. The primary intent was to determine if the soil conditioner, which is marketed in the Midwest, provided significant beneficial effects on these properties as contrasted to the same soil without ALS treatment. The secondary objective was to determine possible interaction effects of this conditioner with soil compaction (no traffic versus traffic in controlled lanes). Soybeans and corn yield measurements were also compared for plots treated and not treated with ALS during 1983, 1986, and 1987.

LOCATION AND METHODOLOGY

SITE DESCRIPTION

An ALS and traffic compaction study was conducted at the Agronomy and Agricultural Engineering Research Center in eastern Boone County, approximately 11 km west of Ames, Iowa, during the summers of 1985 and 1986. Experimental plots were located on a Nicollet silt loam soil (fine-silty, mixed, mesic Aquic Hapludoll) with an average slope of 2%.

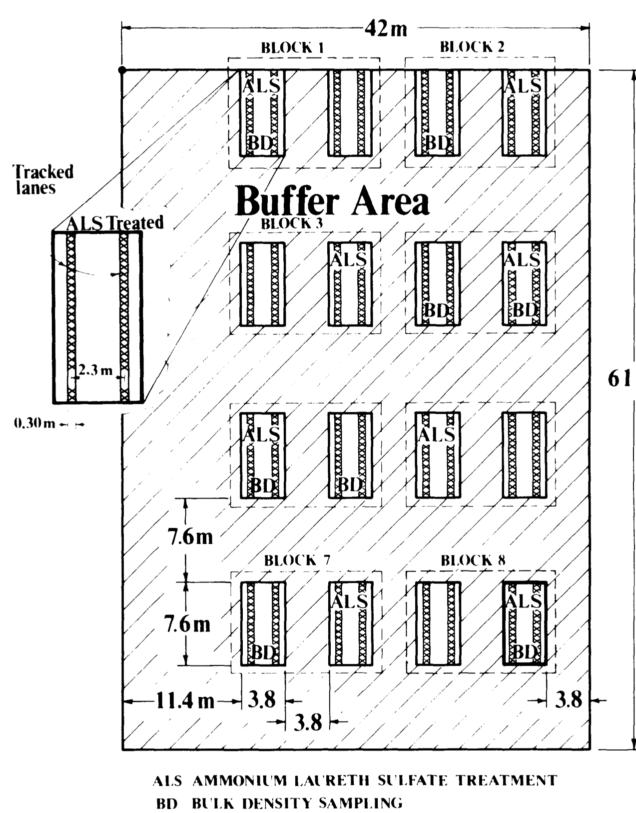

Figure 1–Field plot arrangement showing experimental units, ALS treatment locations, and tracking lanes within individual plots.

The area for this study (see fig. 1) was rectangular, approximately 42 m wide and 61 m long, with individual experimental units 3.8 m wide and 7.6 m long. The 16 experimental units were separated from one another by "buffer" zones measuring 3.8 m in the east-west (E-W) and 7.6 m in the north-south (N-S) directions. The plot area remained fallow during 1985 to allow measurement of soil properties. Soybeans were grown in 1986 followed by corn during 1987, allowing yield measurements to be made during both 1986 and 1987. Soybean yield studies on an adjacent field area were also conducted during 1983.

The field area was moldboard-plowed to a depth of 0.2 m in early May and was disked and field cultivated early in June. Herbicides (Lasso-Amiben) were applied after the secondary tillage operations. The ALS treatment was applied, using a tractor-mounted sprayer, approximately two weeks after secondary tillage. As recommended by representatives of the product manufacturer, the ALS was broadcast applied at the rate of 280 ml (actual product) per hectare. The same amount of water (with and without ALS) was applied to all experimental units at the time of the ALS treatment application. Tillage and tracking operations after plowing were along prescribed traffic lanes. These traffic lanes received tracking from the tractor (Massey Ferguson 1150*, gross weight of 5875 kg) during disking and field cultivation. Tractor compaction (International Harvester 544, gross weight of 2720 kg) along the same traffic lanes occurred during herbicide and ALS applications.

A randomized complete block design was used in assigning the main treatments (ALS or no soil conditioner) to the 16 experimental units, as shown in figure 1. Each block consisted of two experimental units, one receiving the ALS soil conditioner and one receiving no soil conditioner. A split-plot portion of each experimental unit consisted of a compacted lane (due to tractor tracking) and a noncompacted area (no tractor tracking). Measurements of infiltration, soil penetrometer resistance, soil water content, and soil bulk density were periodically made on the split-plot areas (hereinafter referred to as subplots) within the experimental units.

FIELD MEASUREMENTS

Ponded infiltration measurements were made using a double-ring infiltrometer (0.35-m diameter inside ring) following the method outlined by Bouwer (1986). At each measurement location, infiltration of ponded water for a 35-min period was measured and recorded continuously using a float-actuated stage recorder; the apparatus and methods used are described in detail by Mukhtar et al. (1985). On 8 July, two infiltration observations were made for each subplot (compacted and uncompacted) within each of the 16 experimental units. For subsequent dates, only one infiltration observation was made within each subplot. The individual locations for measurements were separated by a minimum of 0.8 m to avoid the potential of lateral movement of water from one location to an adjacent location. On a given date, all infiltration measurements within a given block were made in less than 2 h and for any specific date measurements were completed in one day.

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* Use of a specific product name does not imply endorsement of this product but is included for benefit of the reader.

Soil samples were collected from each subplot to determine soil water content preceding infiltration and soil penetrometer measurements. Soil samples were collected from an undisturbed area immediately outside of the outer ring of the double-ring infiltrometers. In 1985 soil cores were collected for the depth layers of 0-0.075, 0.075-0.15, and 0.15-0.30 m by using a 0.032-m diameter split-tube soil sampler. All soil samples collected were placed in separate soil tins, sealed, and transported to the laboratory for gravimetric soil water determination.

Measurements of soil resistance to penetration were made on each date that infiltration and soil water contents were measured in 1985. Four profiles were measured on each of the subplots (tracked and untracked) nested within the experimental units. Two of the locations were in each of the two wheel tracks for the compacted subplots (four total penetrometer profiles) and four locations were in the uncompacted areas (no traffic). Penetrometer measurements were made for the soil depths of 0-0.05, 0.05-0.10, 0.10-0.15, 0.15-0.20, 0.20-0.25, 0.25-0.30, and 0.30-0.35 m. Sampling locations for these four profiles were separated by a minimum of 3 m in the N-S direction and 1 m in the E-W direction. Care was taken to insure that penetrometer measurements were not made in areas that had received prior infiltration, soil water, soil penetrometer or bulk density sampling.

Twice during 1986 penetrometer readings were made for each plot by using the field sampling arrangement used in 1985. Penetration resistance was measured in 0.1-m increments from the soil surface to the 0.6-m depth. In 1986, soil samples used for soil moisture determinations were collected for depth layers of 0-0.15, 0.15-0.30, 0.30-0.45, and 0.45-0.60 m.

The penetrometer used was a Chatillon, Model DFG-100, with a 12.5-mm diameter, 30-deg cone tip. The procedure used was to zero the display, rest the tip of the cone on the soil surface at the desired sampling location, push the cone into the soil at a constant rate to the desired depth (at the bottom of the sampling layer), record the datum displayed (maximum value), and continue in a similar fashion for the other soil layers. Penetrometer resistance measurements followed the soil cone penetrometer standard (ASAE S313.2, *ASAE Standards*, 1988).

Soil bulk density profiles were determined for both tracked and untracked areas. Undisturbed soil samples were collected from the subplot areas of four ALS-treated and four non-ALS treated plots as shown in figure 1. A powered-auger sampler, similar to that described by Buchele (1961), was used to obtain the undisturbed cores. Soil cores were obtained by allowing the sampler to penetrate to the 0.35-m depth, withdrawing the auger device from the soil, and removing the soil in 0.05-m layers incrementally from the surface layer downward. The cores obtained were 0.075 m in diameter and 0.05 m in depth.

Results and Discussion

The effects of the ALS soil conditioner on soil water infiltration, penetrometer readings, soil moisture content, and soil bulk density are compared under two levels of traffic. Crop yields for the experimental plots and adjacent field areas receiving no treatment and ALS application are also reported for 1983, 1986, and 1987. In almost all instances, the differences in measured soil properties were significant when contrasting the compacted (tracked) to the uncompacted (untracked) subplots. However, the effects of the ALS soil conditioner on soil properties were not significant. Soybean and corn yields were comparable regardless of whether the plots were treated or not treated with ALS.

Infiltration Measurements

Cumulative ponded infiltration measurements were made for the experimental units (conditioner and no conditioner) and subplots (tracked and untracked). Figure 2 for July 24, 1985, shows an example of a plot of cumulative infiltration with time for various treatments. The measured infiltration data were described using the model of Philip (1957), $I = At^{1/2} + Bt$; where I is cumulative infiltration, t is time, and A and B are regression coefficients. Coefficient A is often referred to as the sorptivity and is related to the ability of the soil to absorb or release water, and B depends on the ability of the soil to transmit water.

When the data from all dates are pooled (see Table 1), no significant differences due to ALS are noted. However, the effects of traffic (compaction), date of measurement, and the interaction of compaction by date are all significant or highly significant. When looking at any specific date (data not included), significant differences (at the 5% level) or highly significant differences (at the 1% level) were found when comparing tracked and untracked areas. Lindstrom et al. (1981) also reported that wheel traffic decreased soil water infiltration. Similar to Mitchell (1986) but contrary to Sherwood and Engibous (1953) and Callebaut et al. (1979), these results do not show beneficial infiltration effects caused by application of the soil conditioner.

Moisture Content

The statistical evaluation of moisture contents at the various depths in the soil profile is summarized in Table 1. Similar to the infiltration data, for the top two layers (to a depth of 0.15 m), the effects of tracking (compaction) and date on water content are highly significant, whereas there is no significant effect of the ALS treatment. As would be

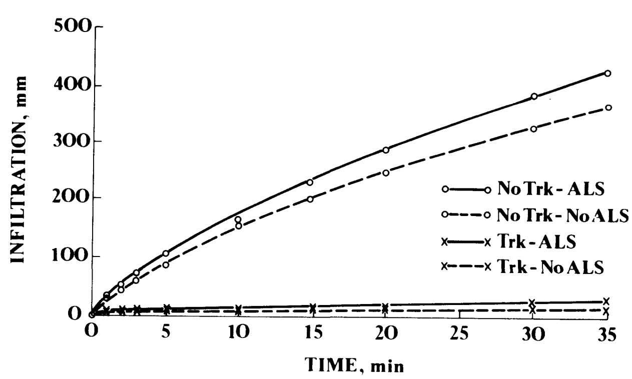

Figure 2–Cumulative infiltration with time, 24 July 1985. (Each value represents the average measurement for eight replications.)

TABLE 1. ANOVA table for selected soil properties, 1985

		Cumulative Infiltration				Soil Water Content						Penetrometer Resistance			
		Philip[a] A Parameter		Philip[a] B Parameter		0-0.075 m		0.075-0.15 m		0.15-0.30 m		0.05-0.10 m		0.20-0.25 m	
Source	df	M.S.	F-test	M.S.	F-test	M.S.	F-test	M.S.	F-test	M.S.	F-test	M.S.	F-test	M.S.	F-test
Block	7	0.647	NS[b]	0.034	NS	0.02	NS	0.002	NS	0.004	NS	605.1	NS	2533.6	9.9**
Conditioner (ALS)	1	0.006	NS	0.002	NS	0.001	NS	0.001	NS	0.001	NS	123.5	NS	94.5	NS
Error a	7	0.475		0.028		0.001		0.001		0.001		221.0		257.0	
Compaction	1	322.0	784**	12.7	423**	0.025	50.4**	0.005	24.5**	0.001	NS	479300	1250**	179400	206**
Cond. & Compact.	1	0.001	NS	0.005	NS	0.001	NS	0.001	NS	0.001	NS	14.18	NS	291.4	NS
Error b	14	0.411		0.030		0.001		0.0002		0.001		383.5		870.8	
Date	3	6.321	4.9**	0.173	3.90*	0.019	23.7**	0.0130	65**	0.0066	33.0**	6603.0	54.8**	2226.6	7.2**
Cond. & Date	3	0.608	NS	0.005	NS	0.001	NS	0.0001	NS	0.0001	NS	14.81	NS	308.1	NS
Compact. & Date	3	13.39	10.4**	0.240	5.5**	0.002	2.7*	0.0013	6.5**	0.0001	NS	4386.0	36.4**	235.1	NS
Cond., Compact. & Date	3	0.510	NS	0.002	NS	0.001	NS	0.0001	NS	0.0001	NS	31.45	NS	210.0	NS
Error c	84	1.289		0.044		0.001		0.0002		0.0002		120.5		307.5	
Total	127														

*, **Significant at 0.05 and 0.01 level, respectively.

[a] Philip Equation, Infiltration = $At^{1/2} + Bt$, where t represents time and A and B are fitted parameters.

[b] NS–Not significant at 0.05 level

expected under natural weather conditions, the soil moisture contents at all depths were significantly influenced by the date of measurement.

Figure 3 presents summary plots of soil moisture data (averaged for each treatment) during 1985. For all dates of measurement, the water content was the least at and near the surface and increased with depth. The effects of tracking were most pronounced for the 0 to 0.075-m layer, with little differences at the deepest layer (0.15 to 0.30 m). This suggests that compaction caused by controlled traffic after primary tillage was limited to the near-surface soil profile.

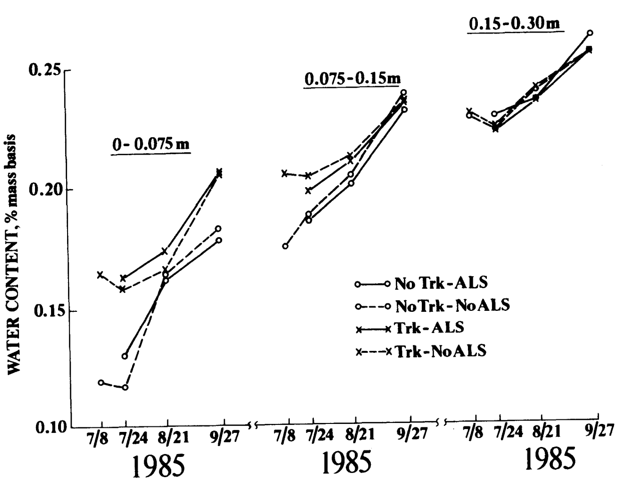

Figure 3–Mean soil water content at selected depths.

Penetrometer Measurements

Assessment of the soil resistance to penetration (a measure of the compacted state of the soil) was periodically made for all plots and treatments. Figure 4 presents a summary of the mean values of penetrometer resistance at selected depths (0.05 to 0.10, 0.20 to 0.25, and 0.30 to 0.35 m) for 1985. The differences in penetrometer measurements between tracked and untracked areas are quite obvious, with the largest differences at the shallow (near surface) depths and decreasing differences deeper in the profile. Compaction due to vehicle traffic after primary tillage (with relatively light-weight power units and equipment) was limited to the upper soil profile. At a depth

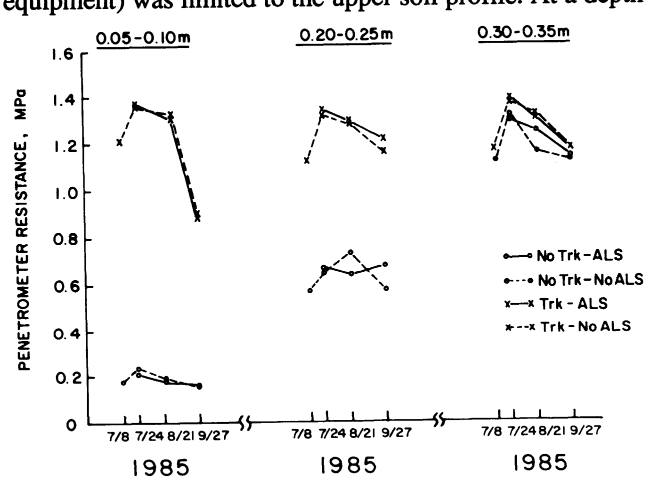

Figure 4–Mean values of soil penetrometer resistance at selected depths.

of 0.30 to 0.35 m (approximately 0.10 to 0.15 m below the depth of tillage), there was minimal difference in the mean value of penetrometer resistance, indicating that the compaction effect of vehicular traffic was limited to the upper, tilled zone. The 1986 penetrometer data show results similar to 1985.

The statistical analyses of penetrometer resistance data are summarized in Table 1. As noted for both the infiltration and moisture content data, there were no significant differences in penetrometer resistance resulting from the ALS treatment when contrasted to the unamended soil. Terry and Nelson (1986) reported that penetrometer resistance was approximately 10 times greater on plots not treated with PAM as contrasted to those receiving PAM treatments. Cook and Nelson (1986) found that PAM applied as granules at the soil surface did not reduce penetrometer resistance; however, when applied as a liquid, the PAM was effective in reducing penetrometer resistance. Effects of compaction (vehicle traffic) and date of measurement were highly significant at both the 0.05 to 0.10-m and 0.20 to 0.25-m depths. The compaction by date interaction was highly significant at 0.05 to 0.10 m but was not significant at 0.20 to 0.25 m.

Soil Bulk Density

Figure 5 shows a plot of the mean soil bulk density with depth for the conditions studied. The effects of tracking (compaction) are clearly evident near the surface. Below 0.25 m there were no significant differences due to traffic. Table 2 presents the analysis of variance for the dry bulk density at the selected depths of 0.05 to 0.10 m and 0.20 to 0.25 m. As illustrated in figure 5, the ANOVA table indicates that there were significant differences caused by compaction at both selected depths. Analysis at each 0.05-m depth increment showed no statistical differences due to traffic below 0.25 m, therefore, indicating that the compaction effects for this study were limited to near the soil surface.

Grain Yields

Figure 6 presents grain yield data for 1983 (from an adjacent field area), 1986, and 1987. The 1986 and 1987 data are yield measurements made on the plot areas used for soil property measurements in 1985. No statistical differences in yield as a response to the soil conditioner treatment were noted. Unfortunately, yield differences caused by compaction treatments are not available.

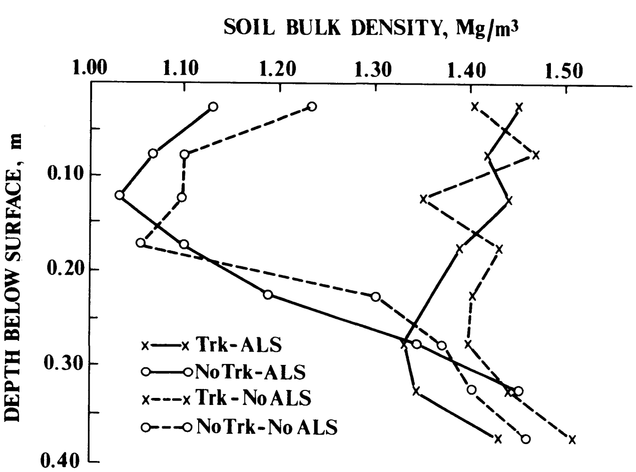

Figure 5–Mean soil bulk density profiles.

TABLE 2. ANOVA table for soil bulk density data

		Soil bulk density			
		0.05-0.10 m		0.20-0.25 m	
Source	df	M.S.	F-test	M.S.	F-test
Block	3	0.0044	NS[a]	0.0343	NS
Conditioner (ALS)	1	0.0085	NS	0.0258	NS
Compaction	1	0.5191	51.9**	0.0767	5.86*
Compaction & Conditioner	1	0.0006	NS	0.0054	NS
Error	9	0.0100		0.0131	
Total	15				

*, ** Significant at 0.05 and 0.01 level, respectively.

[a] NS indicates not significant at 0.05 level.

Conclusions

Soil amendments, such as ammonium laureth sulfate (ALS), are promoted as beneficial in improving soil structure and tilth, near-surface soil fertility, and soil moisture status. Farmers need to know whether they can expect immediate benefits from application of such amendments. Therefore, this study focused on assessing the near-surface effects of ALS on several soil factors and on crop yields during the initial years of application. For all properties investigated, there were no significant differences attributable to the ALS treatment, nor were there any clear interactions of the ALS treatment with other factors. Crop yields were not affected by the ALS treatment. For the short term, there seems to be no benefit (and indeed an out-of-pocket cost) associated with using such a treatment.

On the other hand, as has been indicated in other studies, the effects of traffic on soil compaction and, hence, on soil physical properties are obvious. Increased trafficking causes increased compaction, particularly near the surface, with consistent increases in soil penetration resistance and bulk density. These effects influence the

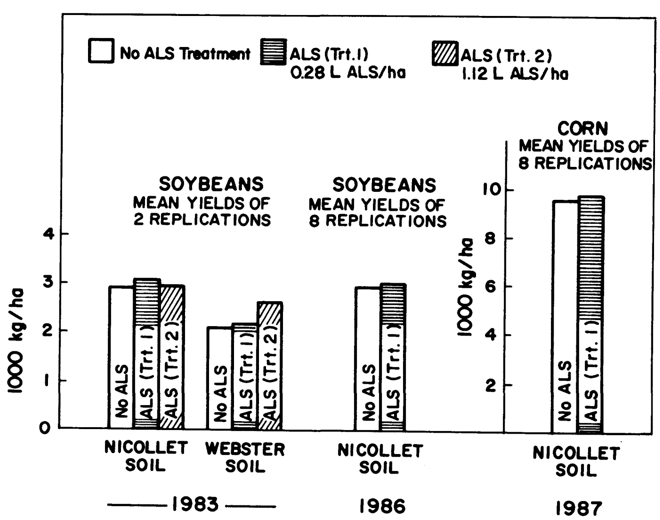

Figure 6–Grain yields for ALS-treated and non-ALS-treated plots.

ease with which water infiltrates into the soil, subsequently affecting soil water storage, runoff, and erosion processes. Although yield differences caused by traffic were not assessed in this study, farmers should be concerned with, and aware of, possible yield effects resulting from high levels of soil compaction.

Additional studies and data on the longer-term effects of ALS on soil physical properties and yield should be performed to determine if such a product may favorably affect soil conditions over time. However, none of the data from this study indicate that soil properties are significantly affected as a result of application of ALS. Presently, farmers would be advised to concentrate on more traditional methods of maintaining a favorable soil environment for crop growth.

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